Lighting and the Office Environment: A Review

Lighting is one of several factors in an individual's working environment. The provision of 'good' lighting may assist in minimizing fatigue, which, if present, can inhibit a worker's efficiency. Fatigue must be addressed in many ways. For an operator of a visual display unit (VDU), lighting factors which may assist performance include a clear screen image without reflections or glare, appropriate ambient light and a view to look at. There are also large differences in the needs of individuals of various ages.

Recommendations about ambient lighting are conflicting. If tasks are screen-based only, lower levels than for general tasks are advocated. Appropriate lighting for any one situation must be determined after a thorough analysis of the task and the individual.

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In recent years, growing numbers of physiotherapists have become involved in treating clients with a variety of work-related problems. In addition, physiotherapists may be called upon to help improve the working environment in a large range of industries. As therapists, it is easy to concentrate on aspects such as posture and repetitive movements. While these are very important, it is also relevant to consider other factors such as lighting, heat, humidity, noise, posture and task organization.

In general, lighting is provided to allow the task to be seen, but it may also contribute to the atmosphere created by the surroundings (Julian and Turner 1980). The Standards Association of Australia (SAA) (1976) take this further, stating that the objectives of good lighting at work include making the task easy to see and providing comfortable lighting.

Achieving the goals of good lighting should assist in optimizing an individual's work performance as indicated by output and/or accuracy. Lighting which is not adequate for the visual task will contribute to the development of a large range of subjective symptoms which together may be termed 'fatigue' and performance may drop significantly (Grandjean 1971). One of the goals of lighting design is to minimize fatigue and so potentially maximize performance.

This paper aims to introduce the basic features of lighting to assist therapists when analysing workstations or to recognise when advice from experts such as Lighting Engineers should be sought. Emphasis will be given to the needs of office workers, particularly operators of screen-based equipment as these workers have an especially demanding visual task (SAA 1987) which is rapidly growing in importance.

For a more detailed, but easily read discussion of most of the points made in this paper, the following booklets in the 'Working Environment Series', published by the Australian Government Publishing Service are recommended:

- No 6. *Artificial Light at Work,* Department of Employment and Industrial Relations (DEIR) (1984)
- No 13. *VDUs at Work,* Department of Science and Technology (DOSAT) (1983) and
- No 16. *Office Design at Work,* Department of Employment and Industrial Relations (DEIR) (1983).

Basic Concepts and Useful Terms

In order to understand how to provide a good visual environment, it is important to understand the major characteristics of lighting and the influence these may have on the eye.

Illumination Measurements

Two measures indicating the overall intensity of light are commonly used. The first is *illuminance* which describes the amount of light falling *on* a surface. It is usually measured in *lux* and changes with the distance between the source and object and with the orientation of the lighted object compared with the light source. At night, under artificial light, most interiors would have illuminance in the range 50-500 lux (Grandjean 1971). A closely related concept is *luminance* which is a measure of the intensity of light projected *from* a surface or object. The surface itself may be luminous *(eg* the surrounds of a fluorescent tube) or it may be reflecting light from another source.

If the light is reflected, the nature of the surface (primarily colour and texture) will largely determine the proportion of incident light that is reflected. This proportion is called *reflectance* (%). The unit for measuring luminance is candela per square metre or cd/m^2 (Julian and Turner 1980, ASA 1987). Within any room, luminance may vary significantly (a prime example being a window and its adjacent wall): the level of variation is termed *contrast,* expressed as a ratio.

Visual Perception

Perception of the visual world is dependent on the individual's visual system. It is worth noting in passing that a relatively small proportion of 'perception' is involved in detecting the existence of a stimulus — recognition of it and decisions about resulting action involve central processing and take much longer.

Humans perceive luminance as the 'brightness' of an object (Erhardt 1984). The visual system can operate over a very large range of luminances but the eye needs to adapt to the prevailing level of brightness in order to be able to discriminate details within the view (or visual field).

Adaptation involves:

(i) A rapid phase, presumably involving neural mechanisms;
(ii) A medium time phase of adjustment of the pupil for size; and
(iii) A slow phase governed by the rates of the photochemical processes (in the retina) involved in reaching an equilibrium (Boyce 1981 p 45).

The third process referred to by Boyce (1981) helps establish the 'overall' level of illumination to which the eye is adapted at any one time, and is relatively slow. Up to an hour may be needed to adapt fully to darkness from a very bright environment such as the beach at noon.

The rods and cones in the retina of the eye are responsible for detecting the light from any object within the visual field. The cones require much higher levels of illumination than the rods for excitation. The density of these receptors varies throughout the retina — with cones being concentrated at the fovea. The image of an object in the centre of the visual field is detected at the fovea and is perceived in greatest detail. Surrounding this region of greatest focus is the middle zone and periphery (Grandjean 1971). In the periphery, rods predominate. They may be excited by very low levels of illumination and are also very sensitive to changes in illuminance. The significance of this is that sources of distraction may be detected by the rods from stimuli that are well away from the area on which an individual is attempting to concentrate. Distractors may include items such as a person moving at another desk, or varying light intensities such as the flicker of a faulty fluorescent tube overhead.

To allow one to see in a three-dimensional world, it is necessary to be able to focus on objects which may be at a variety of distances from the eye. This is largely determined by the state of brightness adaption of the eye and the shape of the lens which can be changed by the ciliary muscle in the eye. Visual *acuity* is the ability to identify fine details at a given distance. This is often assessed clinically by determining how close two objects can be to each other and still be perceived as separate at a distance of six metres from the individual (Julian and Turner

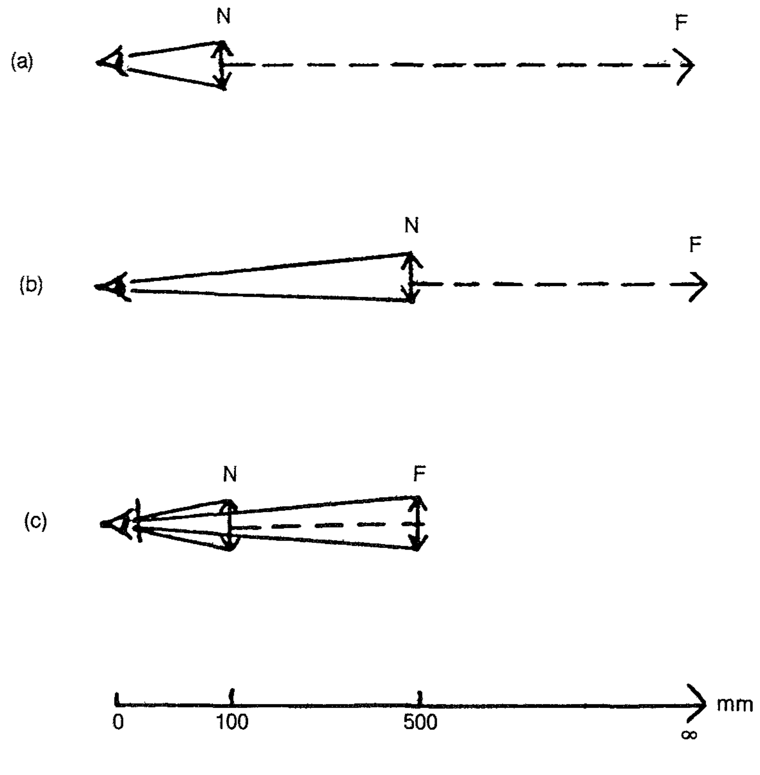

Figure 1: Accommodation: Individuals may focus on objects at any distance between the near point (N) and the far point (F) of their vision. This range varies with age: (a) 20 years, (b) 50 years, (c) 50 years with spectacles. (Adapted from *VDUs at Work,* DOSAT 1983, p14.)

1980). This test may be seen to be inappropriate for office tasks which are usually undertaken within a person's arms length. In general, acuity is improved by increasing the general level of illumination and/or increasing the contrast between the object of regard and its immediate surroundings (Grandjean 1971). *Accommodation* is the process by which the lens of the eye varies in shape to focus on objects at a variety of distances. The range over which a person is able to focus varies significantly with age (DOSAT 1983) (see Figure 1).

Colour

Another attribute of the visual world is the colour of objects or surroundings. Colours have been classified in many ways, but the Munsell system with its 'chips' of colour that may be used as standards for comparison is most useful. In this system, a colour's *hue* is determined by the principle wavelength an object emits or reflects. The *value* of a colour indicates if it is 'light or dark', sometimes referred to as its brightness. A third factor is a colour's *chroma* (or 'saturation') which indicates if mostly one hue or several are present (Hopkinson and Kay 1972). Colour may help an operator to distinguish objects or parts of objects and is particularly useful for hazard identification.

The actual hue or colour perceived by an observer is influenced by the proportion of cones (which individually react maximally to specific wavelengths) that are excited. Overall, humans are maximally sensitive to wavelengths of about 555 μm (Stewart 1980) and this has been used as a basis for developing VDU screens that emit light near this wavelength.

There is also an aesthetic function of colour — it may be used to contribute to the overall 'mood' of a room (DEIR 1984). Appreciation of the colour of a room by most individuals is strongly related to their understanding of the function of the room or the tasks to be performed in it (Whitfield and Wiltshire 1980). The SAA (1987) states that colour contrasts should be kept to a minimum as they may be distracting for visually demanding tasks such as VDU operations. Lowson (1979) suggests that colour should only be used in offices for functional purposes such as indicating emergency buttons, never for decoration.

A more detailed consideration of the aesthetics of colour is beyond the scope of this paper.

Lighting Systems

There are several concepts about lighting systems that are relevant.

Luminaire is the term used to describe a source of illumination, its cover or filter, method of fixation or support and power supply (SAA 1987). A wide variety of luminaires are available, but fluorescent tubes are by far the most common in offices. They are much more efficient (in terms of power used for a given illuminance) than incandescent bulbs and they may operate for many thousands of hours before failure (Grandjean 1971). However, they do present some problems which may be overcome relatively easily.

Firstly, the illuminance of a fluorescent tube varies over time causing a 'flicker'. It occurs at a mains-determined frequency of 50 Hz in Australia which is slow enough to be perceived by the rods. This may constitute a distraction (Isensee and Bennett 1983). Flicker may be eliminated by installing tubes in pairs or groups of three and linking them electronically so that their 'firing rate' is exactly out of phase (Grandjean 1971). This causes the total luminance to be almost constant. A second problem is that a new fluorescent tube has an unreliable output (Zackrison 1983). This author recommends leaving a new tube on for 100 hours continously, preferably in an area set aside for this purpose. After this time its luminance will become more reliable, or it will be obviously faulty and be able to be replaced before final installation. In large buildings such a practice would prove economical in the long term and could be recommended.

Illumination systems may include general lighting which lights the whole area, local lighting to illuminate the task only, or combined systems which use elements of both (DEIR 1984). In offices, fluorescent tubes are common sources of artificial light, but it is also possible to include windows to admit daylight. It is easier to manipulate totally artificial light, but as 90 per cent of workers express a strong preference for a window near their workstation (Treganza *et al* 1974, Knave 1984) lighting designs which allow for this are recommended (see below).

Common Problems for Office Workers

The interaction of lighting systems and our perception of the visual environment may give rise to several problems which can inhibit performance.

Glare

Glare arises where there is a light source or marked contrast in illumination levels within the visual field. Our eyes will adapt to the brighter level and so details in the darker area will be effectively masked. Discrimination loss is greater with higher contrasts and is inversely related to the angle between the source of glare and line of sight (McCormick and Sanders 1982) (see Figure 2). A familiar example of the latter applies when the setting sun shines almost directly in the eyes of a driver, making other cars and the road difficult to distinguish.

To allow maximal task discrimination, the luminance contrast between the task itself, immediate surrounds and periphery should be approximately 10:3:1 or 10:4:3 (Baxter 1980, Smith 1987). If the contrast is much greater than this it may require much more effort to distinguish details in the darker area, causing discomfort glare (De Boer and Fischer 1978). This is a common problem for office workers facing a window and may be overcome

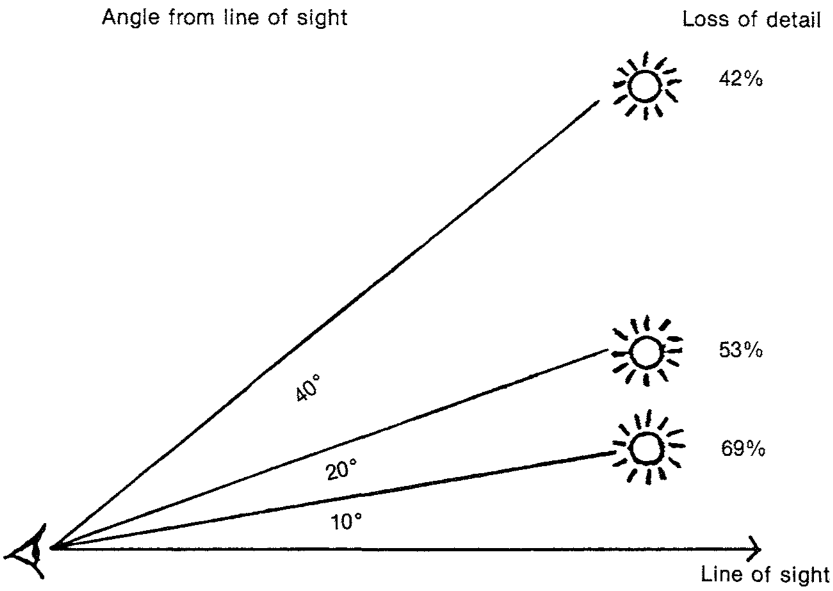

Figure 2: A source of glare will cause decreased ability to discriminate detail, with masking increasing as the source approaches the line of sight. (Adapted from McCormick and Sanders, 1982, p390.)

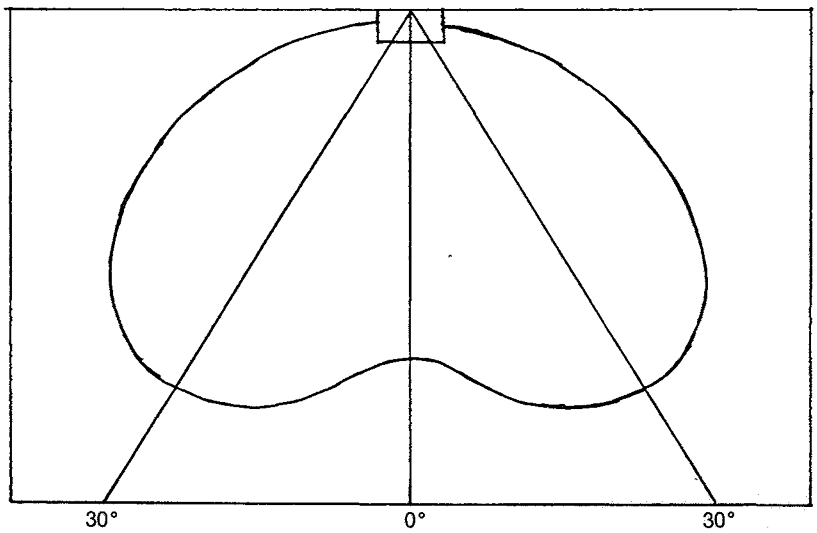

Figure 3: Pattern of emission of light from a luminaire with a 'Batwing' shield. Most of the emitted light is oblique — around 30 degrees from the vertical. (Adapted from Julian and Turner, 1980, pp7-19.)

the general illumination level in the room.

Another common source of discomfort glare arises from looking forward by placing the desk perpendicular to the window (Lowson 1979) or raising at luminaires in front of the individual in a large office. Shields for the light source which cause maximum emission to be oblique are recommended to reduce this (Julian and Turner 1980, Zackrison 1983). These may be called 'Batwing shields' after the shape of a graph comparing intensity with angle of emission (see Figure 3). It is also significant that fluorescent tubes emit more light along their length than from their ends. As a result, positioning a worker so that (s)he sees the tube end on will further reduce glare. This is easily achieved by having desks at right angles to the overhead lights (see Figure 4).

Discomfort glare may constitute a distraction from the main visual task as it is physiologically easier to attend to bright stimuli than dark ones (McCormick and Sanders 1982).

If the contrast between the light source and ambient illumination is so great as to cause an individual to be unable to discriminate details in the darker area, this may be called disability glare. This should not be a problem in modern offices.

Reflections

A second problem which is particularly important for staff using screen based equipment (SBE) is that the screen may reflect sources of illumination or areas of high reflectance. Such reflections may constitute a distraction from perceiving the information on the screen and induce discomfort. Furthermore, reflections, by raising the effective luminance of the screen's background, reduce the contrast between display characters and surrounds. This phenomenon may be termed a 'veiling reflection' and make perception of the information on the screen very difficult (SAA 1976, DOSAT 1983) (see Figure 5).

Reflection reduction is one of the primary requirements of lighting for users of visual display units (VDUs). First steps in removing reflections include reducing ambient light levels, shielding luminaires, and positioning screens at right-angles to windows or artificial light sources (see Figure 4).

It may be seen that there is a conflict in reducing glare from windows by raising general illumination while reducing this to eliminate reflections in

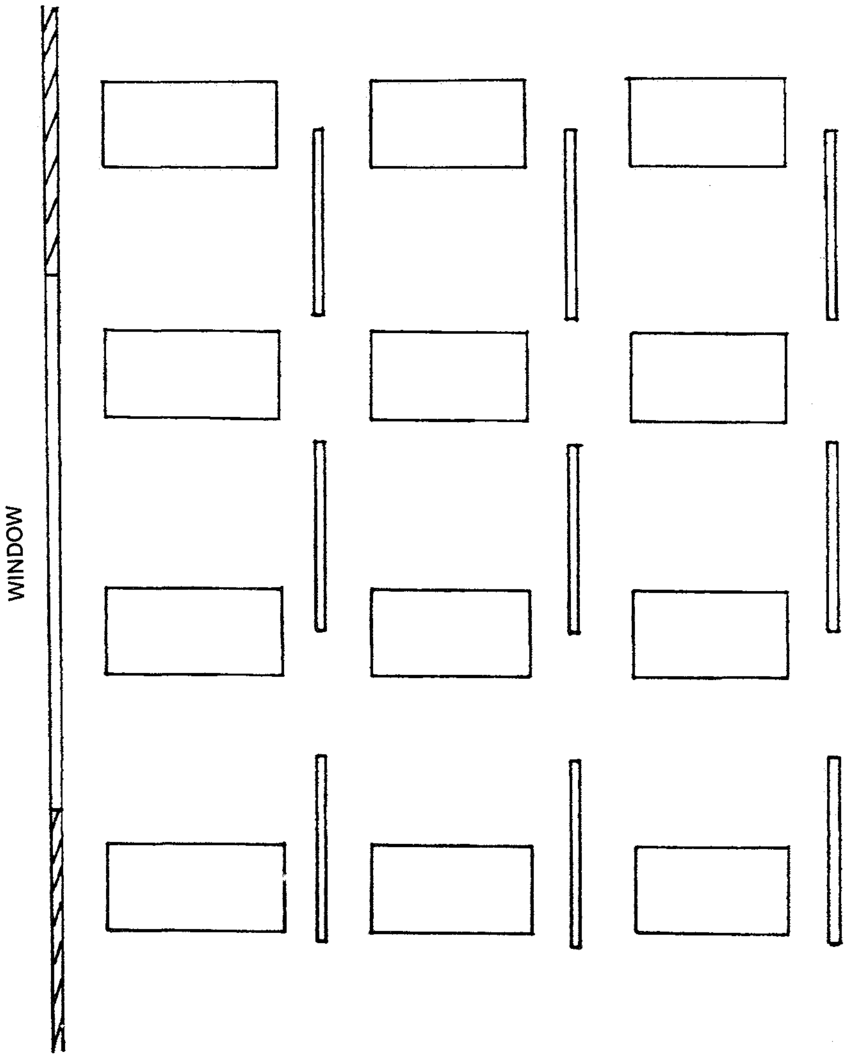

Figure 4: Arranging office furniture so that desks and screens are perpendicular to windows and overhead luminaires is a simple but effective measure to reduce glare and reflections. When windows and fluorescents are not parallel, position desks at right angles to the more troublesome light source.

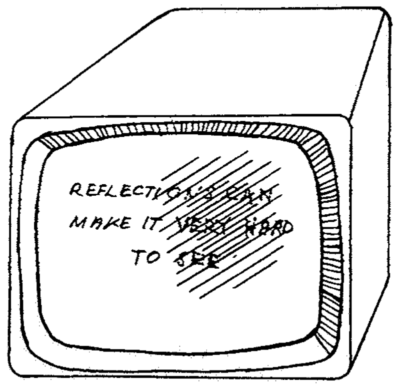

Figure 5: Reflections from luminaires or other objects can significantly reduce the legibility of information on a VDU screen. (Adapted from *VDUs at Work,* DOSAT 1983, pp13 and 14)

VDU screens. Resolving this conflict requires a thorough assessment of the individual workstation.

Fatigue

Fatigue refers to a general set of symptoms which together can significantly reduce a worker's efficiency. Symptoms may derive from the visual system (such as 'double vision', itchy eyes, 'red eyes'), the musculo-skeletal system (commonly neck pain or headache), or 'mental fatigue' as indicated by a subject accepting a poorer performance than normal (Grandjean 1971, Boyce 1981, Smith *et al* 1984). Boyce (1981) argues for the use of subjective measures in rating fatigue, as symptoms are by definition subjective. However, objective measures have been developed, such as decreased acuity, slower accommodation and inconsistencies in eye movements during tracking or reading tasks (Laubli *et al* 1981, Smith *et al* 1984).

Many factors which accelerate the development of fatigue have been identified. They include inadequate lighting (especially sources of glare, low illuminance for non-luminous tasks, or reflections in VDU screens), poor work posture, constrained work postures, and low work satisfaction (DEIR 1983). This last feature is related to:

(i) Task monotony (if only one repetitive task is undertaken);
(ii) Low control by the worker of his or her rate of work or the order in which tasks are performed;
(iii) Anxiety which may be increased if, for instance a worker believes that the task being undertaken is unsafe. Examples of health risks which have been attributed to work with VDUs include Repetition Strain Injury and Radiation hazards (Gunnarsson and Soderberg 1983, Laubli 1981, Stewart 1980).

The severity of fatigue experienced is directly related to the time spent at one task, the number of factors described above that are present and the effort that is required to complete the task (Lowson 1979, Harwood and Foley 1987, Vassilieff and Dain 1986, Gunnarsson and Soderberg 1983).

Overall decreases in productivity due to fatigue are associated with slower reaction times (to respond to the task's demands), or, if the task sets the pace, increased error rates or narrowing of atttention where the individual ignores other sensory inputs (Harwood and Foley 1987, Floru *et al* 1985).

Fatigue is a major problem with up to 84 per cent of workers with SBE complaining of one or more symptoms (Smith *et al* 1984, Gunnarsson and Soderberg 1983). Reducing fatigue is a very complex issue. For office workers, lighting (including the characteristics of the screen for VDU operators) is strongly implicated, but working postures and task organization are also vital (DOSAT 1983).

Principles for Providing a 'Good' Visual Environment in an Office

Types of VDU Tasks

In order to design lighting appropriate for a task, it is necessary to understand the details of that task. Even within the parameters of 'screen-based duties' there is a wide variety of tasks (DOSAT 1983). These may include:

- 'Interactive tasks' where the equipment contributes all the elements necessary for 'input' and 'output' *eg* programming;
- 'Input only' tasks where information based on paper originals is keyed in *eg* calculating wages;
- Other 'input only' tasks where original material may be auditory *eg* word processing from a dictaphone (Laubli 1981).

A further variable is that any of these tasks may take part or all of an individual's working day.

Major Differences Between General Clerical and VDU Tasks

There are several relevant differences between general clerical work and duties involving VDUs.

Firstly, writing and similar tasks normally involve looking down at a horizontal surface, but looking at a VDU screen involves looking forward at a nearly vertical surface. Secondly, as Stewart (1985) points out, if a paper document is hard to read, it is generally easy to move it to 'catch the light'. Thirdly, there is usually a need for a clerical worker to move between his/her own workstation and other areas to consult a supervisor or colleague, to retrieve a file from a cabinet or use a photocopy machine *etc*.

By contrast, there is a tendency for others to bring the work to a VDU workstation rather than the operator going elsewhere to retrieve it (Stewart 1985). With this tendency comes the risk of prolonged periods in one position and thus, accelerated fatigue. Furthermore, with the eyes positioned to focus on the screen, hands on the keyboard and sitting on the chair, a VDU operator has very little chance to vary his/her posture while keying (SAA 1987, DEIR 1983). For this reason, it is imperative that equipment used be adjustable to meet the individual's anthropometric needs and preferably be able to meet the needs of small women to tall men (SAA 1987). It is interesting to note that Australian guidelines (developed by the ACTU in 1982 and reviewed by Helander and Rupp 1984) were the only ones of six international standards at that time to require a screen that tilted and rotated.

Supply of good equipment will not of itself ensure 'good posture'. Operators need to learn how to use it effectively. Even more important in the minimization of fatigue is the provision of regular 'work breaks'. Such breaks (of about 10 minutes in the hour) are becoming part of standard practice (Department of Occupational Health, Safety and Welfare 1987).

Characteristics of the Screen Display

Characteristics of the screen's display are fundamental to the ability to assume a comfortable posture and the effort that will be required to perform the task. An operator must position the head to allow discrimination of the information on the screen and this may or may not require an awkward neck posture. A screen that is easily legible will reduce the need for effort in reading a message and may permit discrimination from a greater variety of eye and head positions.

Factors which affect message *legibility* include character appearance, luminance stability and screen contrast.

The shape, size and spacing of characters are basic to an image's appearance (DOSAT 1983, Stewart 1980, SAA 1987). Helander and Rupp (1984) also advocate the use of 'square or rectangular dots on the screen as they fill the space between adjacent dots better than circular ones' (p187), making the letters look more like the strokes of printed characters. These issues are generally not able to be affected once hardware has been installed, but an awareness of such variables may assist in the choice of future equipment when upgrading is considered.

Flicker is the variation over time in the intensity of the image, causing it to be unstable. Increased effort is needed to discriminate the image as the 'internal and external muscles of the eye [must act] in excess of that required for normal levels of focussing and eye movement' (Isensee and Bennett 1983, p177). Flicker is caused by a difference in the decay rate of the phosphors on the screen and the rate of refreshment by the electron beam (Harwood and Foley 1987). There are significant individual differences in the perception of the *severity* of flicker, although for all individuals it is more severe if the source is in the peripheral zone of vision as may occur if the screen is incorrectly positioned (Isensee and Bennett 1983).

Discrimination of an image is enhanced by increased luminance of the characters, giving a greater contrast between characters and screen background. Luminance is usually adjustable in modern screens. Helander and Rupp (1984) advocate contrasts of as much as 40:1. They point out that other authors have assumed that a contrast of more than 20:1 would result in discomfort glare and that operators often 'prefer contrasts of between 8:1 and 12:1' (p187). These authors suggest that the lower contrasts are chosen because, with most screens, high character luminances cause the dots to 'bloom' and so the characters become less distinct. Such image 'blooming' may impair image recognition more than reduced contrast (Helander and Rupp 1984). Well maintained screens should keep blooming to a minimum.

It is not appropriate to automatically recommend maximal character luminance. Firstly, for a given level of character luminance and screen contrast, discrimination decreases as ambient illumination is raised (Isensee and Bennett 1983, Shahnavaz 1982). Secondly, as screen luminance is raised, the risk of flicker increases (Laubli 1981, Stewart 1980). Thus the screen characteristics must be considered along with ambient illumination.

It may be seen that achieving a good screen image is complex, but it is fundamental to the development of a workstation that will help an operator avoid fatigue. The importance of display quality as a factor in developing fatigue is directly related to the proportion of the working day spent working with the screen and as the SAA (1987) states: 'If the quality of the display is poor, no amount of adjustment of the [remaining] environment will compensate for it' (p14).

Factors in Addition to the Display

As screen luminance, flicker and ambient lighting are all closely linked, optimal image discrimination will require a compromise between these factors.

For VDU based tasks only, it is ideal to reduce ambient lighting significantly (by as much as 50% — SAA 1987) and then for the individual to be able to adjust screen brightness to be maximal without glare or a perceptible flicker. Isensee and Bennett (1983) suggest a character luminance of about 65cd/m^2, while Stewart (1980) recommends a range of between 45 and 100cd/m^2, for characters against a background of 15-20 cd/m^2. Relatively low levels of ambient illumination such as about 250 lux (SAA 1987) will also assist the reduction of direct glare from luminaires when looking forward at the screen and also minimize reflections within the screen, so further enhancing legibility.

The provision of appropriate lighting for operators who must frequently refer to hard copy and to a VDU screen is particularly complex. This is because discrimination of the paper source may well require much higher levels of illuminance than that suggested for VDU usage. Luminaires positioned almost above the operator can achieve the desired high luminance on the source document if the latter is horizontal. However, it is generally recommended that document holders be used to keep source documents nearly vertical to reduce neck flexion and static paravertebral muscle activity. Here it is appropriate to position the workstation so that the light source is slightly behind and on the same side of the operator as the document holder.

Luminaires so positioned may still constitute a source of direct glare for other operators as they look forward at their screens and are also likely to be reflected in the screens. Strategies to overcome glare and reflections include all factors considered above to enhance screen legibility. In addition, the ability to tilt the screen should reduce reflections significantly from overhead sources. Where tilting is not possible the provision of a hood around the screen can assist this.

Another approach to reducing reflections is to fix a filter in front of the screen. Stewart (1980) presents a summary of the different types of filters available and recommends the HEA ('High Anti-Reflection') type because it reduces the luminance of reflections without compromising image clarity. However, it is quite expensive and is rarely cost-effective. The SAA (1987) points out that a cheaper, 'micromesh' filter is in common use but that it may cause a reduction in image quality and difficulty with cleaning (which may further reduce clarity). Such 'add on' attachments are not nearly as effective as initial provision of a good quality screen.

It might seem appropriate for operators using paper documents for general ambient lighting to be at the low levels recommended for screen duties only, with the provision of local lighting over the source. However this is not recommended, as luminaires close enough to the desk to achieve this will be likely to cause hard shadows (SAA 1987) which may mask the source. Also, fixed local luminaires may also cause the adoption of more fixed working postures (Helander and Rupp 1984), accelerating fatigue.

The best solution to this problem appears to have 'moderate' levels of ambient illumination (approximately 500 lux — SAA 1987) with clear screens.

Lighting System Design

It is now appropriate to consider recommended ways in which good ambient illumination can be provided. Firstly, for direct sources (such as ceiling mounted or suspended fluorescents), reflections in VDU screens will be minimized by placing workstations perpendicular to, and between rows of luminaires (SAA 1978, Lowson 1979). Secondly, luminaires should be shielded appropriately. 'Batwing' shields ensure maximal luminance is distributed obliquely, minimizing reflections and glare due to horizontal emission and hard shadows caused by vertical radiation (Zackrison 1983). If feasible, raising the height of the luminaires will also reduce direct glare (see Figures 2 and 6).

Reflection and glare may be further reduced by using indirect lighting systems in which suspended luminaires direct all their emitted light up on the ceiling. The ceiling (which needs to be white or near white) then illuminates the workplace by reflection only. This system effectively reduces glare and screen reflections as there are no 'hard'

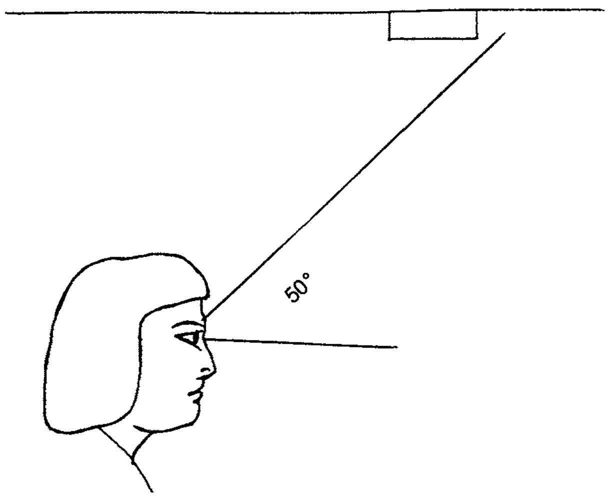

Figure 6: A luminaire positioned more than 50 degrees above the horizontal line of sight should cause minimal discomfort glare. (Adapted from *VDUs at Work,* DOSAT 1983, p8 and *Artificial Light at Work,* DEIR 1984, p35.)

light sources. There may be a significant reduction in efficiency as up to 30 per cent of light is absorbed, not reflected, by the ceiling depending on its colour. However, with large banks of luminaires, adequate general levels should be attained and such a system may be recommended as being 'most satisfactory' for the majority of workstations (SAA 1987, Lowson 1979).

Another approach to having illumination with minimal glare is provision of a 'luminous ceiling' (Smith 1981). This involves installation of luminaires in the ceiling cavity above a matrix of prisms which direct light obliquely to all workstations. Although a very expensive option it can be most effective (Smith 1981, Julian and Turner 1980).

For those workers whose duties involve both general office and screen-based tasks, a combination of the approaches outlined above may be considered. It would be satisfactory for all workstations to be designed for operators using SBE and paper documents. An alternative would be for a small area to be set aside for VDU use with low general lighting if no hard copy is used when at the screen. High ambient illumination could then be permitted in the 'general area'. This would allow ideal lighting in both areas and would ensure 'built in' posture breaks as workers move between the areas. For those fortunate enough to have such a variety of tasks, this design is to be recommended.

One final factor pertinent to both ambient illumination and minimization of fatigue is the provision of windows. Daylight entering through windows may be considered to be a useful source of illuminance if, for instance the opposite walls have a high reflectance (Paix 1977). However, given that daylight varies so much over time, and can only effectively penetrate an office to a depth of less than three times the window height (SAA 1976, Paix 1977), it is difficult to achieve 'good daylighting' and so supplementary artificial lighting is essential for adequate illuminance.

However windows and daylight also serve another purpose: they give a view of the 'outside world' (Boyce 1981, Hopkinson and Kay 1972). There is strong evidence that people prefer to work with such an external view (Knave 1984, Treganza *et al* 1974).

By looking through a window at a distant view, workers may relieve tension in the muscles normally involved in focussing on the screen and desk (SAA 1987). Such 'visual relief' can significantly reduce fatigue and is recommended for all office workers. However, if it is not feasible to permit all individuals to look through a window then pictures or posters of natural scenes are very effective in providing 'visual rest centres'. The SAA (1987) and DOSAT (1983) both recommend the use of such measures.

Individual Differences: Ageing

The performance of an individual's visual system varies significantly with age.

There is a gradual loss in the range of accommodation (see Figure 1), and the rate of accommodation is slower in older workers (Boyce 1973, Vassilieff and Dain 1986). The latter authors, in a study of the wearers of bifocal spectacles using VDUs, found that up to about 55 years of age this problem can be effectively removed by provision of bifocals achieving 'standard' optometric goals. However, for older users, spectacles for this task may need to be specifically prescribed. This seems reasonable given that a VDU screen is commonly 35-70cm from the viewer compared with a reading distance of 25-40cm for paper copy (Helander and Rupp 1984).

Light entering the eye of older workers is scattered and absorbed more by the lens which is less compliant and more opaque than in younger individuals (Boyce 1981). This causes a decrease in the total amount of light able to be detected by the rods and cones of the retina, and also in poorer discrimination of details, that is, decreased acuity (Grandjean 1971). As a result, workers of 60 years or more will show a significant improvement in performance with higher levels of task luminance, even though this may make little difference to their colleagues in their twenties (Boyce 1981). Light adaptation is also slower for older individuals who may thus be more susceptible to perceiving screen flicker (Boyce 1981, Vassilieff and Dain 1986).

Most of these problems may be overcome by the provision of optimal lighting, adjustable screen and special glasses, if needed (SAA 1987).

It is worth noting that Zackrison (1983) found that staff over 50 years of age are more likely to be managers not operators, and so the significance of increasing visual problems may not be as high as implied by the objective changes in the persons' visual system.

Summary of Recommendations in the Literature

Given the large differences between tasks and individuals, it is difficult to make specific recommendations about standards for visual tasks. However, various authors have attempted to do so.

Considering ambient illumination levels, recommendations for general office work have included:

400 lux (SAA 1976, Baxter 1980, DEIR 1984)

500-700 lux (Hopkinson and Kay 1972)

500-1000 lux (De Boer and Fischer 1978)

1000-1500 lux (Helander and Rupp 1984)

For VDU based tasks, the situation is just as confused. Recommendations have included:

150-300 lux (ACTU/VHC 1982 — quoted in Helander and Rupp 1984)

About 50% less than SAA 1976, therefore about 200-300 lux (SAA 1987)

240 lux (Shahnavaz 1982, who suggests VDU operations at night should be in 184 lux)

300-500 lux (Helander and Rupp 1984, Stewart 1980)

Thus it appears necessary to give general guidelines, based on the principles of comfortable lighting. Baxter (1980) recommends that for each task, there should be a range of illumination levels with weightings to account for individual differences within each range. De Boer and Fischer (1978) state that these recommended ranges should be based on 'preferred' levels as established by experiment and questionnaire. Alternatively, Treganza *et al* (1974) state that most workers can be satisfied with ambient levels anywhere within a broad range so long as there are individual controls of specific elements.

Conclusions

Appropriate lighting for any one situation must be determined after a detailed analysis of the needs of the task and the individual worker. It is apparent that for operators with screen-based tasks only, provision of relatively low levels of ambient illumination (250-300 lux) is appropriate. Up to 500 lux for work involving reference to hard copy or general clerical duties may be recommended. However, because of the important interaction in the effects of screen display, ambient illumination and individual characteristics, the level of ambient illumination is less important than the provision of equipment that includes legible screen characters, variable screen brightness and adjustable furniture configuration (Shahnavaz 1982, Rogers *et al* 1986, Stewart 1985).

Workstations should be positioned between and perpendicular to fluorescent tubes and these luminaires should be shielded to ensure maximal emission is obligue (Cuttle 1979, Stewart 1980). Alternatively, indirect lighting systems are most effective as these minimize sources of reflections and excessive contrast (SAA 1976, 1987).

A visual rest centre such as a picture or window is also highly recommended (SAA 1987).

Systems that are simple to maintain are generally preferable as maintenance, if complicated, is likely to be neglected (Boyce 1981) and if so, up to 50 per cent of output may be absorbed by dust on the luminaires (Lowson 1979). The importance of maintenance in the basic planning of any installation is emphasized by DEIR (1984).

Providing a 'comfortable' visual environment is one important factor in avoiding occupational fatigue. However, it must be considered in conjunction with appropriate postures at work, work breaks and task organization to facilitate task variety and work satisfaction. Successful provision of all these factors should assist in attaining optimal performance.

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